PB-217 381

CHARACTERIZATION OF BENTHIC SEDIMENTS OF THE ST. CROIX RIVER

Warren H. Oldaker, et al

Federal Water Pollution Control Administration
Boston, Massachusetts

August 1968

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

37
(CWT-10-2)

U.S. F.W.P.C.A. - NE Re.

PB 217 381
CWT-10-2

CHARACTERIZATION OF BENTHIC SEDIMENTS OF THE ST. CROIX RIVER

Prepared For

International Joint Commission
Advisory Board on Pollution Control
St. Croix River

RECEIVED
LIBRARY
MAY 13 1969
FWPCA, OHIO BASIN REGION
4676 COLUMBIA PKWY., CINTI, O. 45226

LIBRARY
MAR 21 1969
FWPCA, OHIO BASIN REGION
CINTI., O. 45226

U. S. Department of the Interior
Federal Water Pollution Control Administration
Northeast Region
Boston, Massachusetts
August, 1968

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield VA 22151

18

CWT-10-2

CHARACTERIZATION OF BENTHIC SEDIMENTS OF THE ST. CROIX RIVER

By

Warren H. Oldaker
Edward L. Taylor

Prepared For

International Joint Commission
Advisory Board on Pollution Control
St. Croix River

U. S. Department of the Interior
Federal Water Pollution Control Administration
Northeast Region
Boston, Massachusetts
August, 1968

18

CHARACTERIZATION OF BENTHIC SEDIMENTS

During the survey[1] by the U.S. Army, Corps of Engineers to determine the location and volume of benthic sediments in the St. Croix River, in Maine and New Brunswick, portions from each boring were analyzed by the laboratory of the Federal Water Pollution Control Administration. Organic carbon and organic nitrogen were determined for the samples, and the results are shown in Table 1. The purposes of the laboratory study were to attempt to characterize the sediments and substantiate the physical findings of the Corps of Engineers.

Principles of soil science have characterized soil in terms of their mineralogical character, physiochemical properties and biological composition. Characterization has also included the behavior of inorganic and organic nitrogen and phosphorous reaction mechanisms with subsequent fixation, release and degradation. Factors affecting movement of major and minor plant nutrients in soils demand close appraisal of the soils to support predictions of growth potential characteristics. The carbon to nitrogen ratio (C:N) is widely used in agriculture to indicate past, present and future capabilities for crop growth.

The C:N ratio of arable soils range from 8:1 to 15:1 with the median ranging from 10:1 to 12:1.[2] The variability of the C:N ratio of potential soil components is illustrated by the following: C:N ranges from 20 or 30 to 1 for legumes, beans and farm manure to as high as 90 to 1 for straw. Bacteria and proteinaceous matter, on the other hand, have a much narrower range from 4:1 to 9:1.

The constancy of the C:N ratio in any particular soil is the fundamental basis for its use. Only when organic decay of soil components is present, does the C:N ratio significantly change. As decay occurs, carbon dioxide is evolved as the eventual end product while nitrogen is retained in the microorganisms responsible for the breakdown of the carbonaceous material. As metabolic activities continue, the C:N ratio steadily decreases, with eventual decrease in activity and number of organisms. Ammonia begins to appear once biological demand for nitrogen decreases. Nitrification causes nitrate-nitrogen to appear which is soluble and may thereby be leached from the soil. The rate of loss of carbon as carbon dioxide to the environment and nitrogen, as soluble nitrate-nitrogen, eventually stabilizes to yield a constant C:N ratio in the soil.

The major value of the carbon to nitrogen ratio in soils is as a predictive index based upon a knowledge that constancy of the index in arable soils has been achieved. Since benthic sediments are primarily unconsolidated deposits polluted with human and industrial wastes, the predictive value of a soil index such as the C:N ratio to those sediments has met with little success. Depression of the dissolved oxygen profile in a stream may depend to a great extent on the original source and chemical composition of the benthic sediments.(3) Decomposition of the settled organics releases gas, lifting these sediments to the water surface where they float and eventually redeposit. Many mineral exchanges occur between the deposits and overlying water. Iron, nitrate-nitrogen, and phosphorous may degrade water quality by encouraging algal growths.(4) Subsequent decomposition of extensive algal growths may kill great numbers

of fish.[5] Sediment type often controls the kinds of organisms found. For example, rat-tailed maggots, sewage flies and sludge worms are especially adapted to certain sludge deposits and low dissolved oxygen conditions.[6]

Use of organic carbon and organic nitrogen to characterize a benthic sediment has been described by Ballinger.[7] The product of the percent organic carbon and organic nitrogen, is termed the Organic Sediment Index (OSI) and is intended to serve as a single index of relative organic concentration in certain bottom deposits. The product of a multiplication is not unique and characteristic of the factors such as the carbon and nitrogen values. Use of the OSI to characterize a sediment needs further amplification such as the separate generation of several organic sediment indices of various substrates such as peat, clay, etc., followed by a comparative analysis. The need to combine the two concepts, i.e., chemical characterization by carbon and nitrogen followed by reference to a specific major waste component in the benthic sediment under study, led to the expression which is termed the F-index. The derivation of this index is presented in the Appendix. Sediments in the St. Croix River are characterized by the use of this expression.

When a scatter diagram was drawn of the OSI and F values, there appeared to be little correlation between these two parameters. A correlation coefficient (r) was determined to give a qualitative indication of the strength of the relationship between these variables. A correlation coefficient close to zero indicates that the regression line is incapable of prediction and close to ± 1 for a line capable of nearly perfect prediction.

The correlation coefficient was found to be +0.28. The data are tabulated in Table 1 and plotted on Figure 1.

In the F study, the organic carbon value and the organic nitrogen value of blue clay found in this stream and of groundwood taken from the St. Croix Paper Company were used as reference parameters. This Company has manufactured groundwood pulp for many years, along with sulfite pulp and, more recently, Kraft pulp. Many years ago, saw mills existed along this stream, although none do so today. Thus blue clay and groundwood appear to be logical reference parameters to characterize the benthic sediments taken from this stream. Having chosen these two parameters, it is now possible to describe, using the F-index, the magnitude of change that a certain benthic sediment varies from the natural clay base. The F values for the blue clay and groundwood in the St. Croix River area are respectively 0.54 and 2.08. An F value $\leq$ 0.54 indicates that the sediment is effectively a natural sediment in terms of the organic carbon and organic nitrogen to be found there. If the value of F is approximately 2.08, then in terms of organic carbon and organic nitrogen, the sediment resembles groundwood. Values of F for sediments do not indicate either consolidation, stabilization, quantity or the biological availability of components.

Although the value of F for blue clay was 0.54, the incorporation of various amounts of inorganic matter such as sand or gravel may lower this value. Also, naturally occurring humus may raise the value. In view of these possibilities, an F value of 0.8 or less is chosen to represent

the natural stream bed material. For further sediment characterization and analysis, a value of 1.3 was obtained when the sediment is composed, by weight, of 50 percent groundwood and 50 percent blue clay. An additional reference value of 2.1 indicates that the sediment is, in terms of organic carbon and organic nitrogen, principally composed of groundwood.

Using these three F values (0.8, 1.3, and 2.1) as reference points, the data shown in Table 1 may be conveniently arranged into three geographic study sections (see Table 2).

Fifty percent of the samples taken from the five-mile stream reach between Woodland Dam and the point where the river makes a sharp bend to the north just upstream of Baring, Maine resembled natural blue clay (cross sections 10+00 to 240+00 in Corps of Engineers Survey). Twenty-eight percent of the samples from this area resembled groundwood, with the remaining samples having intermediate characteristics.

The second geographic section, from the point just upstream of Baring near Haywood Island to the downstream boundary of Baring, has quite different characteristics (cross sections 250+00 through 330+00). Only 16 percent of the samples resembled blue clay and 68 percent of the samples resembled groundwood, with the remaining samples having intermediate characteristics.

The significance of the sharp increase of F-index in geographic section No. 2 should not be overlooked. There may be three possibilities: river ponding, with consequent sediment deposition; introduction of new

components into the stream and marked decay of sediments already laid down in the stream; or their various combinations.

Reference to Figure 1 and the engineering report [1] indicates a very definite ponded area from cross section 250+00 through cross section 330+00. There are no significant odor comments on the engineering logs. The area is essentially uninhabited with no known sources of sewage entering the stream. Therefore, the high F values were apparently due to the ponding of the river waters, with subsequent settling of suspended sediments.

In the third section, from the downstream boundary of Baring at the beginning of Moosehead National Wildlife Refuge to the International Bridge at Calais, Maine(cross section 350+00 through 550+00), 28 percent of the samples resembled blue clay, 33 percent resembled groundwood and the balance showed intermediate characteristics. Core No. 67 taken from cross section 568+00 was not included in this reach since it was a bank sample.

Thus, it is apparent that in the second geographical section a majority of the benthic sediments more closely resembled groundwood than either of the other two sections. The first and third sections contain approximately the same percentage of samples whose principal composition resembled groundwood.

Use of the F-index yields close agreement with observations contained in the field engineer's report.[1] The report states that 91.3 percent

of the unconsolidated bottom deposits were found to occur from a bend of the river just upstream of Baring (in the vicinity of cross section 250+00) to the dam at Milltown, New Brunswick. Hence, both the engineering estimate and the values of F obtained for the different sediments characterize this area as the most likely area from which to remove bottom material.

Based on the chemical analysis of the sediments and their characterization by the F-index, it appears that from cross section 350+00 through cross section 550+00, dredging is not indicated. Reference to Table 2 indicates that geographical study section 3 closely resembles section 1. Thirty-two percent of the samples in reach 1 had F values $\geq$ 1.4 and 48 percent of the samples in reach 3 had F values $\geq$ 1.4. It appears that on the basis of laboratory investigation, considerations such as sediment volume, degree of consolidation, etc. must be more closely evaluated to more directly justify dredging of the sediments in study reach 3.

References

1. Report on Cross-Section and Sampling Survey, St. Croix River, Maine-New Brunswick. Department of the Army, New England Division COE, Waltham, Massachusetts (January 1968).

2. Anderson, M.S. and Byer, H.G. - The Carbon Nitrogen Ratio in relation to Soil Classification. Soil Science 38, 121 (1934).

3. Velz, C.J. - Significance of Organic Sludge Deposits. Technical Report W 58-2, USDHEW,PHS (1955).

4. Fertilization and Algae in Lake Sebasticook, Maine, USDHEW, FWPCA Technical Services Program, TA&I Branch (Jan. 1966).

5. MacKenthun, K.M. and Herman, E.F. - A Heavy Mortality of Fishes Resulting from the Decomposition of Algae in the Yahara River, Wisconsin. Biology of Water Pollution Control, pgs. 75-78, USDI, FWPCA (1967).

6. Bartsch, A.F. and Ingram, W.H. - Stream Life and the Pollution Environment - IEID, pgs. 119-127, USDI, FWPCA, (1967).

7. Ballinger, D.G. - Unpublished Report - Chemical Characterization of Bottom Sediments, USDI,FWPCA (1968).

APPENDIX

Mathematical Derivation of F-Index Values:

In this study, the values of organic carbon and nitrogen for blue clay and groundwood are used as reference parameters to characterize the benthic sediments. The carbon of the natural stream bed (blue clay) is designated C_{bm} while the organic nitrogen of the natural stream bed is designated N_{bm}.

The F-index is written mathematically:

$$F = \frac{\frac{C_s}{C_{ac}} + \frac{N_s}{N_{ac}}}{C_{bm} + N_{bm}}$$

Where:

C_s = amount, in grams, of organic carbon found in 100 grams of sediment sample.

C_{ac} = amount, in grams, of organic carbon found in 100 grams of any single component known to exist in the sediment.

N_{ac} = amount, in grams, of organic nitrogen found in 100 grams of any single component known to exist in the sediment.

C_{bm} = amount, in grams, of organic carbon found in 100 grams of the natural base material of the stream bed.

N_{bm} = amount, in grams, of organic nitrogen found in the natural base material of the stream bed.

N_s = amount, in grams, of organic nitrogen found in 100 grams of sediment sample.

Chemical analysis of the blue clay from the St. Croix River yields 0.9 grams of organic carbon (C_{bm}) and 0.06 grams of organic nitrogen (N_{bm}). Groundwood from the St. Croix Paper Company contains 47.4 grams of carbon (C_{ac}) and 0.12 grams of organic nitrogen (N_{ac}).

Using the equation and data given above, the F value for blue clay is 0.54 and the F value for groundwood is 2.08.

TABLE 1

F-INDEX, ORGANIC SEDIMENT INDEX (OSI)
AND CHEMICAL DATA FOR THE ST. CROIX RIVER

Cross Section*	Log Number	% Organic Carbon	% Organic Nitrogen	F-Index	OSI
10+00	69	20.0	0.21	2.29	4.20
50+00	84	10.0	0.09	1.00	0.90
50+00	85	3.8	0.12	1.12	0.46
55+00	86	34.6	0.49	5.01	16.95
55+00	87	6.6	0.07	0.76	0.46
60+00	88	40.4	0.61	6.18	2.46
60+00	89	2.3	0.02	0.22	0.05
60+00	90	27.1	0.23	2.59	6.23
60+00	91	1.7	0.05	0.47	0.08
70+00	97	34.2	0.69	6.74	23.60
70+00	95	6.9	0.13	1.29	0.90
70+00	94	2.3	0.09	0.83	0.21
70+00	96	6.8	0.16	1.54	1.09
90+00	93	26.6	0.19	2.23	5.05
90+00	92	30.4	0.70	6.82	21.28
150+00	50	0.7	0.06	0.54	0.04
150+00	51	6.9	0.06	0.67	0.04
150+00	52	1.7	0.02	0.56	0.03
150+00	53	1.4	0.04	0.55	0.06
160+00	56	35.0	0.66	6.49	23.10
160+00	54	< 0.3	0.08	0.69	0.02
160+00	55	0.3	0.03	0.27	0.01
180+00	58	0.7	0.04	0.36	0.03
180+00	57	0.5	0.04	0.36	0.02
180+00	59	13.0	0.11	1.24	1.43
190+00	46	0.6	0.07	0.07	0.04
190+00	45	0.9	0.03	0.28	0.03
190+00	44	2.0	0.09	0.82	0.18

*Downstream of Dam at Baileyville, Maine

TABLE 1 (Continued)

Cross Section	Log Number	% Organic Carbon	% Organic Nitrogen	F-Index	OSI
200+00	48	3.5	0.13	1.20	0.46
200+00	49	0.4	0.04	0.36	0.02
200+00	47	<0.3	0.03	0.26	0.01
210+00	61	4.9	0.07	0.71	0.31
220+00	62	39.0	0.37	4.06	14.43
220+00	63	0.4	0.01	0.09	0.00
230+00	64	1.6	0.04	0.29	0.06
230+00	74	5.0	0.28	2.54	1.40
230+00	75	12.1	0.10	1.13	1.21
240+00	65	9.6	0.24	2.29	2.30
240+00	76	6.7	0.07	0.75	0.47
240+00	77	2.0	0.16	1.43	0.32
250+00	70	2.8	0.12	1.10	0.34
250+00	66	12.6	0.29	2.79	3.65
250+00	71	7.9	0.19	1.82	1.50
250+00	73	6.2	0.39	3.52	2.42
250+00	72	3.6	0.07	0.69	0.25
265+00	78	7.7	0.07	0.78	0.54
265+00	79	36.3	0.40	4.27	14.52
265+00	80	31.3	0.27	3.03	8.45
265+00	81	17.0	0.27	2.72	4.59
265+00	82	20.8	0.22	2.36	4.58
270+00	83	1.9	0.08	0.74	0.15
300+00	16	38.0	0.36	3.96	13.68
300+00	17	20.8	0.23	2.45	4.78
300+00	18	46.2	0.37	4.22	17.09
300+00	19	41.7	0.31	3.60	12.93
310+00	20	14.0	0.13	1.43	1.82
310+00	21	30.4	0.25	2.84	7.60
310+00	98	44.2	0.29	3.48	12.82
310+00	2	36.2	0.36	3.86	13.03
310+00	22	32.0	0.19	2.35	6.08
310+00	23	31.5	0.48	4.86	15.12

TABLE 1 (Continued)

	Cross Section	Log Number	% Organic Carbon	% Organic Nitrogen	F-index	OSI
	320+00	100	46.6	0.53	5.62	24.70
	320+00	24	33.5	0.30	3.34	10.05
	320+00	25	10.2	0.07	0.83	0.71
	320+00	26	25.4	0.29	3.07	7.37
	320+00	27	15.3	0.16	1.72	2.45
	320+00	28	0.8	0.02	0.19	0.02
	330+00	10	27.5	0.28	3.03	7.70
	330+00	11	19.4	0.20	2.16	3.88
	330+00	12	12.8	0.14	1.49	1.79
	330+00	13	38.3	0.28	3.27	10.72
	350+00	109	8.0	0.34	3.13	2.72
	350+00	14	3.4	0.05	0.15	0.17
	350+00	15	7.8	0.10	1.04	0.78
	350+00	1	< 0.1	0.03	-	-
	350+00	29	3.5	0.14	1.29	0.49
	350+00	30	6.0	0.08	0.83	0.48
	370+00	31	0.9	0.02	1.76	0.02
	370+00	32	8.7	0.17	1.67	1.48
	370+00	33	2.2	0.11	1.00	0.24
	370+00	101	4.6	0.12	1.14	0.55
~	370+00	3	24.1	0.88	8.16	21.21
	390+00	34	3.3	0.04	0.42	0.13
	390+00	35	11.1	0.02	0.41	0.22
	390+00	36	42.5	0.34	3.88	14.45
	390+00	102	4.1	0.09	0.87	0.37
~	390+00	108	19.7	0.43	4.16	8.47
~	390+00	4	4.2	0.25	2.26	1.05
	400+00	5	4.8	0.32	2.88	1.54
	400+00	37	1.4	0.03	0.29	0.04
	400+00	8	3.8	0.08	0.78	0.30
	400+00	7	8.5	0.22	2.10	1.87
	400+00	103	22.6	0.30	3.10	6.78
	420+00	9	4.1	0.07	0.70	0.29
	420+00	39	0.4	0.07	0.62	0.03
	420+00	38	3.5	0.19	1.73	0.67
~	420+00	104	0.9	0.06	0.54	0.05
~	420+00	105	4.8	0.18	1.67	0.86

TABLE 1 (Continued)

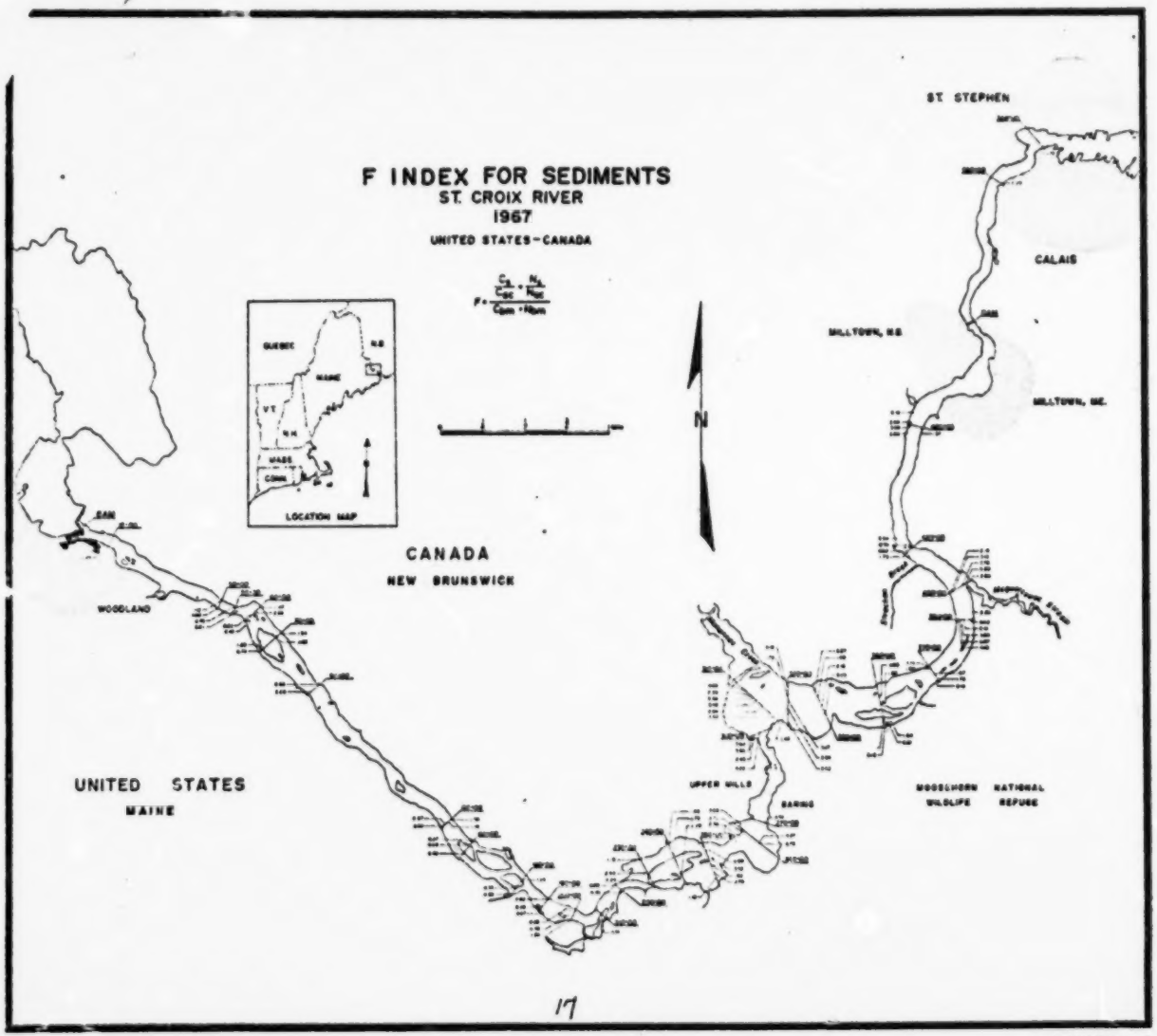
Cross Section	Log Number	% Organic Carbon	% Organic Nitrogen	F-Index	OSI
~ 460+00	106	5.3	0.32	2.89	1.90
460+00	40	3.0	0.15	1.37	0.45
460+00	41	< 0.3	0.02	-	-
460+00	43	6.6	0.38	3.44	2.51
460+00	42	24.1	0.33	3.39	7.95
~ 460+00	107	7.1	0.57	5.10	4.05
550+00	68	1.1	0.02	0.20	0.02
568+00	67	16.3	0.16	1.74	2.61

~ = approximately

TABLE 2

CHARACTERIZATION OF BENTHIC SEDIMENTS
ST. CROIX RIVER

Geographical Study Section	Cross-Section From-Through	F-Index Ranges (Percent of samples occuring within the designated ranges)			
		0-0.8	0.9-1.3	1.4-2.1	$\geq$ 2.2
1	10+00-240+00	50	18	4	28
2	250+00-330+00	16	3	13	68
3	350+00-550+00	28	24	15	33


F INDEX FOR SEDIMENTS
ST. CROIX RIVER
1967
UNITED STATES-CANADA
ST. STEPHEN
CALAIS
MILLTOWN, N.B.
MILLTOWN, ME.
CANADA
NEW BRUNSWICK
WOODLAND
UNITED STATES
MAINE
UPPER MILLS
BARING
MOOSEHORN NATIONAL WILDLIFE REFUGE
LOCATION MAP
N

17

FIGURE 1